IS 8843 (1978): Accuracy requirements for turbine gears
[PGD 31: Bolts, Nuts and Fasteners Accessories]

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IS : 8843 - 1978

(Reaffirmed 2001)

Indian Standard

ACCURACY REQUIREMENTS FOR TURBINE GEARS

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INDIAN STANDARDS INSTITUTION
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NEW DELHI 110002

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Indian Standard
ACCURACY REQUIREMENTS FOR TURBINE GEARS

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Indian Standard
ACCURACY REQUIREMENTS FOR TURBINE GEARS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 15 May 1978, after the draft finalized by the Gears Sectional Committee had been approved by the Mechanical Engineering Divisional Council.

0.2 In the preparation of this standard considerable assistance has been derived from BS 1807 : 1976 'Specification for marine main propulsion gears and similar drives : metric module' issued by the British Standards Institution.

0.3 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard specifies basic tooth form modules and accuracy requirements of high grade helical gears for turbine and similar drives. It does not, at present, cover gear loading and IS : 4460-1967† shall be used for rating of these gears. This standard applies to four classes of gears, designated as Class A0, Class A1, Class A2 and Class B. Class A0 is the highest.

1.1.1 The accuracies laid down for Classes A0, A1, and A2 are generally appropriate for gears running at pitch line speeds higher than about 50 m/s or where any other factor demands the highest class. For lower pitch line speeds, the standards of accuracy laid down for Class B will generally be appropriate.

2. TERMINOLOGY

2.1 For the purpose of this standard, the terms, definitions and notations shall be as given in IS : 2458-1965‡ and IS : 2467-1963§. Additionally

*Rules for rounding off numerical values (*revised*).

†Method for rating of machine cut spur and helical gears.

‡Glossary of terms for toothed gearing.

§Notation for toothed gearing.

following notations have also been used :

Full indicator movement	FIM
Diameter for journal	d_j
Axial runout	F_q
Radial runout	F_r
Selected measurement length	L_m
Bearing span	L_s
Reference surface	RS

2.2 Nomenclature for Double-Reduction Gear Trains — The descriptions used for the double-reduction gear trains shall be those given in Fig. 1 to Fig. 4. In these figures, only one gear train is shown for convenience, but the terminology used is equally applicable to systems having more than one gear train.

3. TOOTH PROFILE

3.1 Basic Rack Tooth Profile — The tooth profile normal to the helix shall correspond to 20° pressure angle as shown in Fig. 5. The basic rack form for 20° pressure angle profile is straight sided except that a slight relieving of the tip of the tooth is permissible. The amount of this easing shall not exceed that shown in Fig. 5.

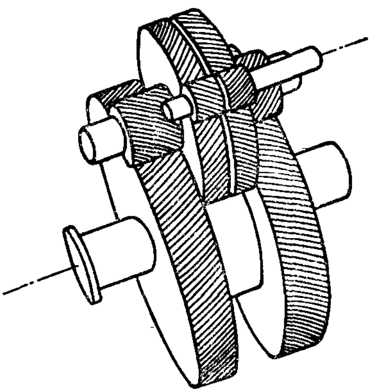


FIG. 1 SPLIT SECONDARY GEAR TRAIN

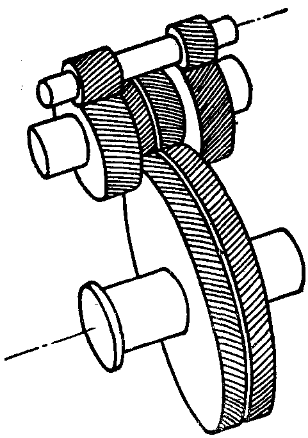
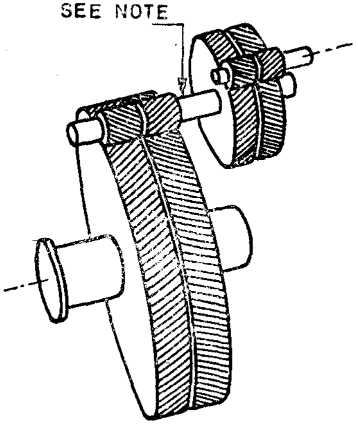
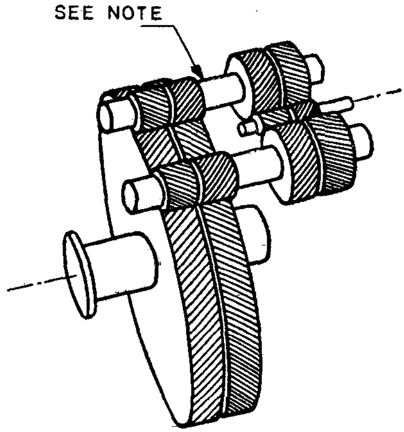


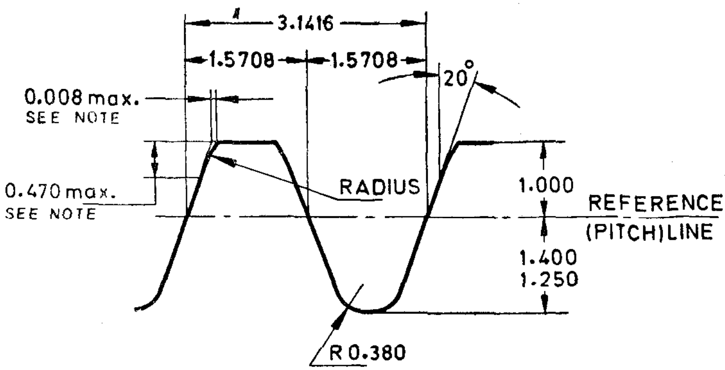
FIG. 2 SPLIT PRIMARY GEAR TRAIN





NOTE — If a flexible coupling is used between primary and secondary gears, the drive is described as a tandem articulated gear train.

FIG. 3 TANDEM GEAR TRAIN FIG. 4 DUAL TANDEM GEAR TRAIN



NOTE 1 — If preferred by the manufacturer, the profile relief may be carried out on the lower part of the teeth near the root. If the teeth of the mating gears are relieved at the tips and the roots, the tip relief of either added to the root relief of its mate shall not exceed the amount given in Figure.

NOTE 2 — The 20° pressure angle basic rack form is consistent with that given in IS : 2535-1978 'Basic rack and modules of cylindrical gears for general engineering and heavy engineering (*second revision*)' but the extent to which modification can be incorporated has been restricted in this standard.

FIG. 5 20° PRESSURE ANGLE BASIC RACK TOOTH PROFILE FOR UNIT NORMAL MODULE

4. STANDARD NORMAL MODULES

4.1 The normal modules shall be selected from the following, giving preference to the first choice values. These modules have been selected from IS : 2535-1978*.

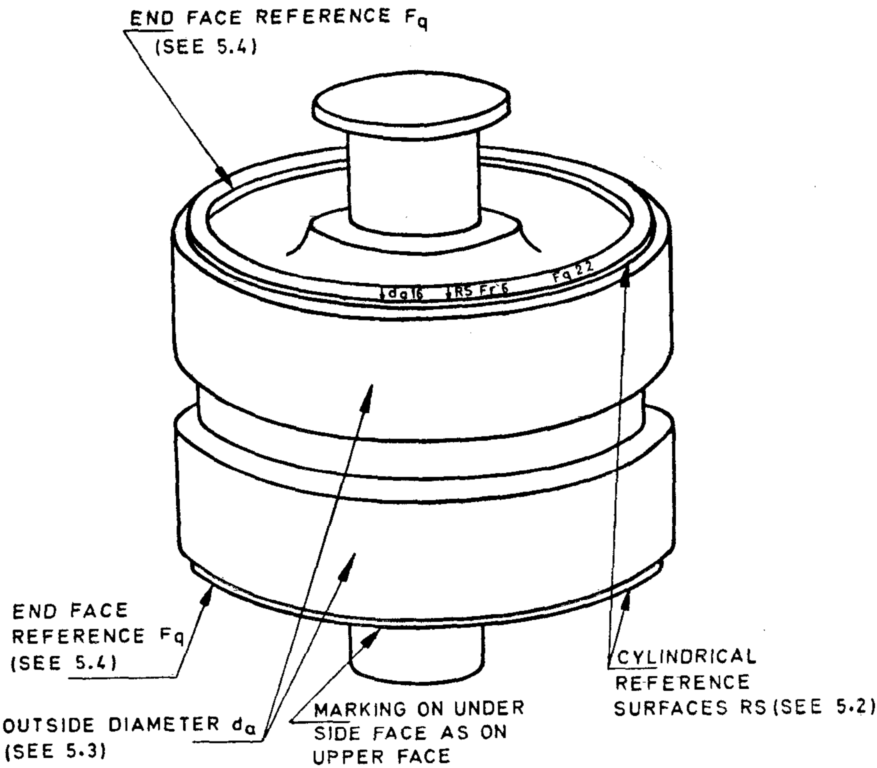
Normal Modules, m_n (mm)

First Choice	*Second Choice*
2	2·25
2·5	2·75
3	3·5
4	
5	4·5
6	5·5
8	7
10	9
12	11
16	14

5. ACCURACY REQUIREMENTS FOR GEAR BLANKS

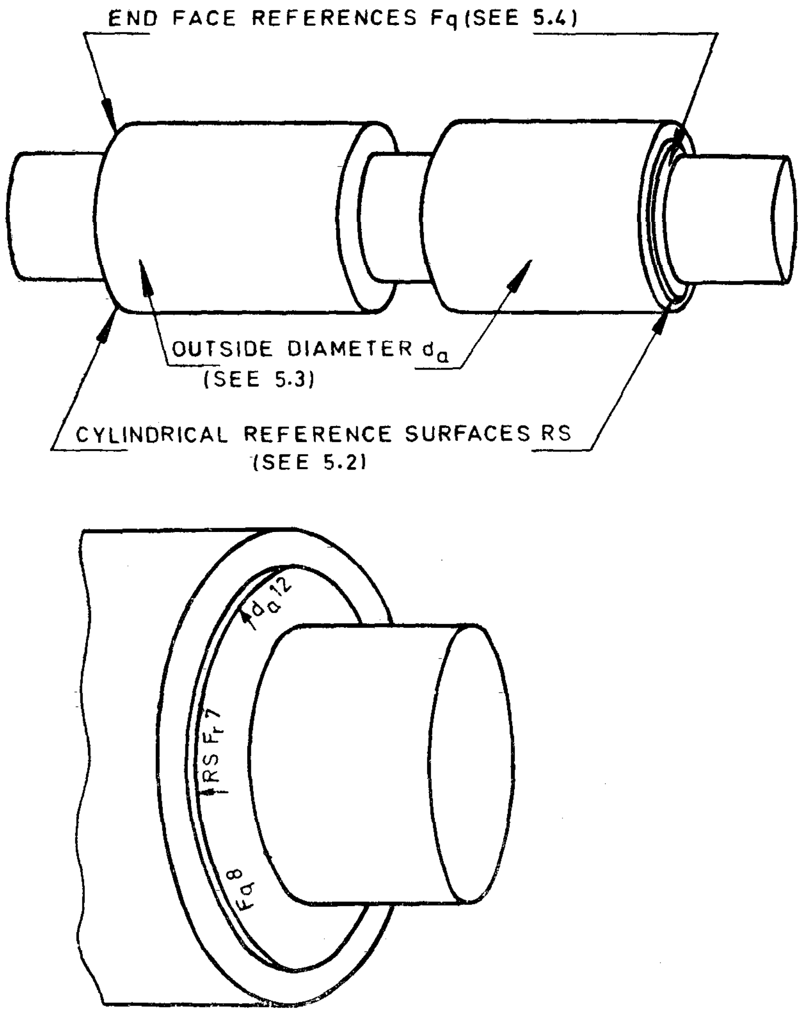
5.1 Reference Surfaces — To facilitate setting-up for gear cutting and subsequent pitch measurements, suitable radial and axial reference surfaces shall be provided. The tip surface, if so desired, may be designated as a reference face (*see* Fig. 6 and Fig. 7).

*Basic rack and modules of cylindrical gears for general engineering and heavy engineering (*second revision*).



NOTE — The markings, for example, d_a 16, shall be in characters about 3 mm high and any burrs raised by marking shall be carefully removed so as not to interfere with the accuracy of the surface.

FIG. 6 RECOMMENDATIONS REGARDING MARKING ON REFERENCE SURFACES ON WHEEL



NOTE — The markings, for example, d_a 12, shall be in characters about 3 mm high and any burrs raised by marking shall be carefully removed so as not to interfere with the accuracy of the surface.

FIG. 7 RECOMMENDATIONS REGARDING MARKING ON REFERENCE SURFACE ON PINION

5.2 Runout of Reference Surfaces with Relation to Journals — Radial or axial runout should be measured in the appropriate direction with dial gauges at two positions on the reference surface. When measurement is made on the machine these should be located at 90° and 180° to the position of the turning tool or grinding wheel. The full indicator measurement (FIM), while the gear blank is rotated through one revolution, shall not exceed:

Grades A0, A1 and A2	$(0{\cdot}015\, d' + 5)$ µm
Grade B	$(0{\cdot}02\, d' + 10)$ µm

This measurement shall be made by the manufacturer and its value shall be permanently marked in micrometres, preceded by the letters RSF_q or RSF_r as appropriate on the end faces of the blank adjacent to the reference surfaces at the point of maximum indicator reading. When the tip surface is designated as a reference surface the letters d_a should precede F_r.

5.3 Runout of Outside Diameter of Blank with Relation to Journals — When the outside diameter of the gear blank is to be used to facilitate pitch measurement, a dial gauge should be applied at two positions on the outer cylindrical surface of the gear blank. When measurement is made on the machine these should be located at 90° and 180° to the position of the turning tool or grinding wheel. The FIM, while the gear blank is rotated through one revolution, shall not exceed:

Grades A0, A1 and A2	$(0{\cdot}015\, d' + 5)$ µm
Grade B	$(0{\cdot}02\, d' + 10)$ µm

This measurement shall be made by the manufacturer and its value shall be permanently marked in micrometres, preceded by the letters d_a on the end face of the rim at the point of maximum indicator reading (*see* Fig. 6 and Fig. 7).

5.4 Axial Runout (Wobble) — The axial runout of the end faces of a gear with relation to its journals shall be measured by the manufacturer whilst the blank is still mounted in the lathe or grinding machine after finishing. It shall be measured by rotating the gear and applying a dial gauge to the axial reference surface. Readings shall be taken at two positions, one of which shall be at 90° and the other at 180° to the position of turning tool or grinding wheel.

The FIM at either position during one revolution of the blank shall not exceed:

Grade A0, A1 and A2	$(0{\cdot}01\, d' + 5)$ µm
Grade B	$(0{\cdot}015\, d' \pm 5)$ µm

This measurement shall be made by the manufacturer and its value shall be permanently marked in micrometres, preceded by the letters F_q on the end face of the gear at the point of maximum indicator reading (*see* Fig. 6 and Fig. 7).

5.5 Outside Diameter of Blank — The tolerance for all grades is:

$$\begin{matrix} +0 \\ -(10_{pn} + 0{\cdot}05\, d')\ \mu m \end{matrix}$$

For convenience of subsequent gear cutting and inspection operations, the measured diameter of the blank at each end shall be recorded.

In the case of a double helical gear, the blank shall be measured at each end of working face.

6. ACCURACY OF WHEELS AND PINIONS

6.1 Undulations

6.1.1 *Classes A0 and A1* — The amplitude of the combined undulations, as recorded at any ball setting shall not exceed 5 µm.

6.1.2 *Classes A2 and B* — The amplitude of any undulation arising from any individual source, measured at approximately the mid-depth of the working surface of the tooth, shall not exceed:

Class A2	$(0{\cdot}001\, d + 5)\ \mu m$
Class B	$(0{\cdot}001\,5\, d + 7{\cdot}5)\ \mu m$

where d is pitch diameter of the wheel or pinion in mm.

The amplitude of the combined undulations for Classes A2 and B as recorded at any ball setting, shall not exceed one and a half times the amount given above.

NOTE — For each ball setting of the measuring instrument, readings shall be taken on four teeth 90° apart and the length of instrument traverse shall be as large as is practicable.

6.2 Transverse Pitch

6.2.1 *Determination of Cumulative Pitch Error* — Readings shall be taken in a transverse plane in equal spans of teeth around the total circumference of the gear. The contact points of the instrument shall, at each successive setting, be so located that one contact point occupies ideally the same position on the tooth profile as was previously occupied by the other contact point. The length of each span measured shall be as large as is practicable with the gauge used, noting that the product of the number of spans measured and the number of teeth in each span shall be as nearly as possible equal to the number of teeth in the gear.

The error over any span is the difference between the reading for this span and the mean of the readings for all the similar spans comprising the complete circumferences.

A minimum of ten spans shall be considered in building upon cumulative error curve.

6.2.2 *Determination of Single-Pitch Errors* — Readings of the pitch errors of adjacent teeth shall be taken over at least as many successive pitches as comprise of one span of the reading for cumulative pitch error, at a minimum of three equally spaced spans around the gear.

The readings shall be taken in two transverse planes whose distance apart, measured along with the helix, is one half of the wavelength of the dominant undulation. The average of the two readings taken in respect of any single pair of adjacent teeth shall be regarded as the pitch measurement for that particular pair of adjacent teeth.

The difference between this measurement and the average of all the readings taken for the span shall be regarded as the single pitch error for that particular pair of adjacent teeth.

If agreed between purchaser and manufacturer, measurements for single pitch error may be taken normal to the tooth, in which case the value of L_m in the formulae in **6.2.3** becomes the normal pitch.

6.2.3 *Tolerances* — The cumulative and single pitch errors, measured over any selected length of arc, shall not exceed:

Grade A0 $(0{\cdot}75\sqrt{L_m} - 1)$ µm, subject to a lower limit of 7·5 µm for cumulative and short span errors. Single pitch errors shall not exceed 5 µm. The records of single pitch errors are to be used to assess the zones where the short span errors are the largest.

Grade A1 5 µm less than Grade A2 or 5 µm, whichever is the greater.

Grade A2 $(1{\cdot}25\sqrt{L_m} + 3{\cdot}3)$ µm.

Grade B $(2\sqrt{L_m} + 5)$ µm.

where L_m does not exceed $\pi d'/2$ mm.

For Class A1 wheels and pinions the allowable cumulative pitch error over any span shall be 0·005 mm less than the value permitted for Class A2 or 0·005 mm whichever is greater.

For convenience, permissible errors in accordance with these formulae are shown in Fig. 8.

NOTE — The measurement of single pitch error may be influenced by the difficulty of locating the gauge and by the effect of such characteristics in the gear as the super imposition of undulations of differing wavelengths, and by the surface texture of the tooth flanks.

It shall not be obligatory for measurements of adjacent pitch error to be taken provided that the machine on which the gear has been cut has been within its preceding 10 000 hours use or at least within the preceeding three years, subjected to the pitch test and straight spur gears blank.

6.2.4 *Matching of Cumulative Pitch Error* — The difference between the cumulative pitch errors on the two helices of a double helical gear, measured over the corresponding arc lengths, shall not exceed one half of the amount specified in **6.2.3** by more than 8 µm. The application of this is illustrated in Appendix A.

6.3 Axial Pitch

6.3.1 *Measurement of Axial Pitch* — The measurements shall be taken in axial planes about 120° apart.

6.3.2 *Tolerances* — The measurement of the axial pitch of the pinion shall not differ from a measurement of the axial pitch of the wheel by more than the following amount per 250 mm length, allowance being made for any designed difference in axial pitch between the wheel and pinion:

Classes A0, A1	(6·25 cosec β) µm
Class A2	(8·75 cosec β) µm
Class B	(15 cosec β) µm

If the contact marking complies with the requirements of **7.5.2** the axial pitch measurements taken shall be regarded as for record purpose only, or for use when supplying a replacement pinion.

6.4 Profile Error — The profile error shall not exceed the following amount:

Classes A0, A1 and A2	($0{\cdot}6 p_t + 5$) µm
Class B	($0{\cdot}8 p_t + 5$) µm

The profile error shall not have a positive value, except within the middle third of the tooth depth where a positive valve of ($0{\cdot}1 p_t + 2{\cdot}5$) micrometre is permissible within the above overall tolerance. A positive value indicates excess material on the profile.

For Class A0, only a measurement of pressure angle shall be made. Base pitch shall not depart from the nominal by more than ± 10 µm. Profile deviations from this datum shall be as indicated above. Profiles of mating gears are to be complementary with 10 µm over the middle 60 percent of the profile. In view of the difficulties of measurement, the profile tolerances shall apply only when expressly agreed between the purchaser and the manufacturer.

6.5 Tooth Thickness and Backlash — The backlash between any pair of gears shall be not less than the amount given by the following formula:

$$\text{Minimum normal backlash } \frac{a \propto n}{60\,000} + 0{\cdot}127 \text{ mm}$$

The maximum backlash shall be agreed between the purchaser and the manufacturer. In general the maximum backlash shall not exceed three times that given by the above formula.

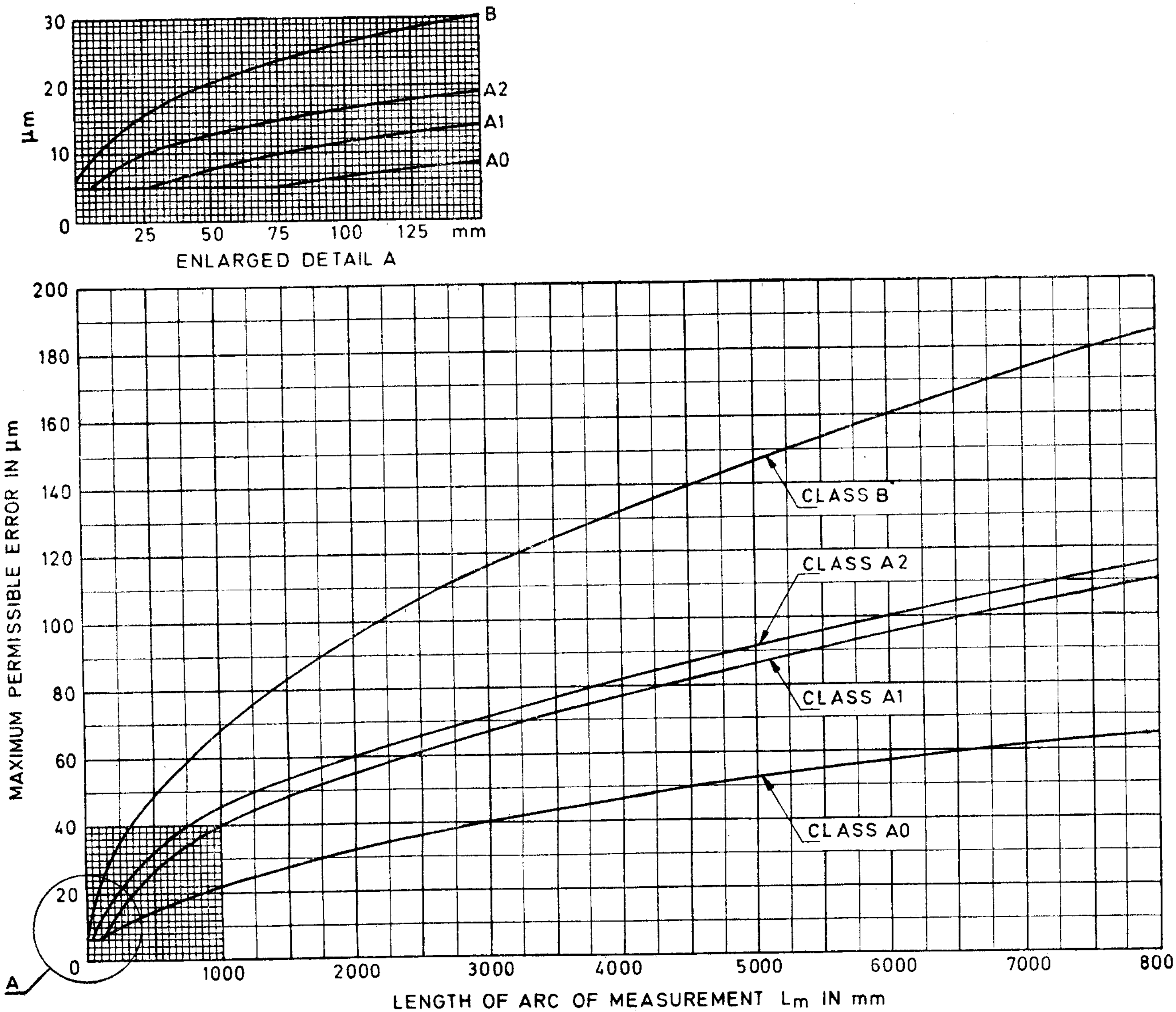


FIG. 8 CHART OF MAXIMUM PERMISSIBLE CUMULATIVE AND SINGLE PITCH ERRORS

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The proportionate distribution of the total backlash between wheel and pinion shall be at the discretion of the manufacturer.

The depth of the tooth shall, in no case, be more than 0·152 mm less than the designed figure but may be greater than the designed figure at the discretion of the manufacturer.

Where the actual diameter of the blank differs from the designed diameter a corresponding adjustment shall be made in the depth of the tooth to give the correct root diameter.

NOTE — The above rules for backlash and limitation of working depth are based on the assumption that the straight sided portion of the hob tooth near its tip extends to at least the full working depth line. On this basis, expansion in working should not cause the tip of one member to foul the root fillet of the other.

7. ACCURACY REQUIREMENTS FOR ASSEMBLY

7.1 Assembly — When it is necessary for a gear to be cut separately from its shaft, its concentricity and axial runout (wobble) shall be measured after final assembly. This test shall be conducted between centres or on rollers and the tolerances given in **5.2** to **5.4** shall apply.

7.2 Roundness, Parallelism and Coaxiality of Journals — Each journal shall be both round and parallel to within ($0{\cdot}02\, dj + 7{\cdot}5$) µm.

A test for the combined effects of departures from roundness and coaxiality of the two journals shall be made by rotating the mounted gear with each journal resting in its bearing. The total range of indicator reading taken at any point on the top of either journal during one complete revolution should not exceed ($0{\cdot}025\, dj + 10$) µm.

7.3 Journal and Bearing Assembly — After the fitting and adjustment of the journals in their bearings, the difference in clearance between the two bearings shall not exceed:

a) for bearings of single helical gears: $\frac{8Ls}{b}$ µm

b) for outer bearings of double helical gears: $\frac{16Ls}{b}$ µm

Where there is a centre bearing, the difference in clearance between each outer bearing and the centre bearing shall not exceed $\frac{8Ls}{b}$ µm

7.4 Balancing — The gear train elements with pitch-line speeds higher than 50 m/s shall be dynamically balanced and lower speed elements shall be statically balanced.

7.5 Meshing

7.5.1 *Assembly Test* — The errors of meshing shall be determined, at the manufacturer's option, with the gears assembled in the gear case, in a meshing frame or in V-blocks. If the test is made in the gear case or a meshing frame, the bearings shall be without oil clearance.

The alignment of the shafts for the purpose of this test shall comply with the following:

a) The difference between the centre distance at the journals at each end of the shafts shall not exceed ($0{\cdot}01\ a + 5$) μm.

b) The mean centre distance shall be correct to within ($0{\cdot}04\,a$ + 10) μm.

c) The departure of the centre point of any one journal from the plane containing the centre points of the other three journals shall not exceed ($0{\cdot}01\ Ls + 7{\cdot}5$) μm.

7.5.2 *Contact Marking* — The teeth of the pinion and the wheel shall be in turn coated with marking compound a thin film of tool maker's blue or lacquer and the gears rotated at a slow speed under sufficient torque to ensure contact between the teeth.

The mesh contact marking shall cover the following amounts of tooth flank area on each helix:

a) *Class A0* — At least 50 percent of the working depth for 50 percent of the facewidth and at least 40 percent of the working depth for a further 40 percent of the facewidth;

b) *Class A1* — At least 40 percent of the working depth for 50 percent of the facewidth and at least 20 percent of the working depth for a further 40 percent of the facewidth;

c) *Class A2* — At least 40 percent of the working depth for 35 percent of the facewidth and at least 20 percent of the working depth for a further 35 percent of the facewidth; and

d) *Class B* — At least 40 percent of the working depth for 25 percent of the facewidth and at least 20 percent of the working depth for a further 25 percent of the facewidth.

7.6 Load Test — A further check on the contact marking shall be made after the gears have been run under service load in the gear case.

Before the gears are run under load, a thin coat of permanent dye in lacquer shall be applied with a soft brush to the teeth of the pinion, and one, or two axial bands about 150 mm wide on the teeth of the wheel.

The coating shall comply with the following requirements:

a) The constituents of the lacquer shall be soluble in the spirit base;

b) The lacquer shall be unaffected by hot lubricating oil; and

c) The thickness of the coat shall not exceed 0·005 mm.

After the gears have been run under service load the accuracy of meshing, as indicated by the areas from which the lacquer has been removed, shall be not less than that specified in **7.5.2** for the assembly test.

APPENDIX A

(*Clause* 6.2.4)

MATCHING OF CUMULATIVE PITCH ERRORS

A-1. This appendix illustrates the application of **6.2.4** on the matching of cumulative pitch errors, taking two examples from a large gear wheel.

Details of wheel: 3 840 mm pitch circle diameter

640 teeth

18·849 6 mm transverse pitch

Cumulative pitch measurements taken in spans of eight teeth for each helix are plotted in Fig. 9, the numbering of the spans for each helix commencing from the same position on the circumference of the wheel. In the figure the continuous line represents measurements of the right-hand helix and the interrupted line represents measurements of the left-hand helix.

Example 1 :

Pitch errors for spans 34 and 35

$$L_{m1} = 8 \times 18{\cdot}849\,6 = 150{\cdot}796\,8 \text{ mm}$$

Allowable cumulative pitch error from **6.2.3** for Class A2 is

$$1{\cdot}25\sqrt{150{\cdot}796\,8} + 3{\cdot}3 = 18{\cdot}65\ \mu\text{m}$$

Allowable matching error from **6.2.4** is $0{\cdot}5 \times (18{\cdot}65) + 8 = 17{\cdot}32\ \mu\text{m}$

Cumulative pitch error length X_1 from Fig. 9 corresponding to span 34 = $19{\cdot}27\ \mu\text{m}$

Cumulative pitch error length Y_1 from Fig. 9 corresponding to span 35 = $33{\cdot}02\ \mu\text{m}$

Matching error $= Y_1 - X_1$

$= 33{\cdot}02 - 19{\cdot}27$

$= 13{\cdot}75\ \mu\text{m}$, which is less than the amount permitted

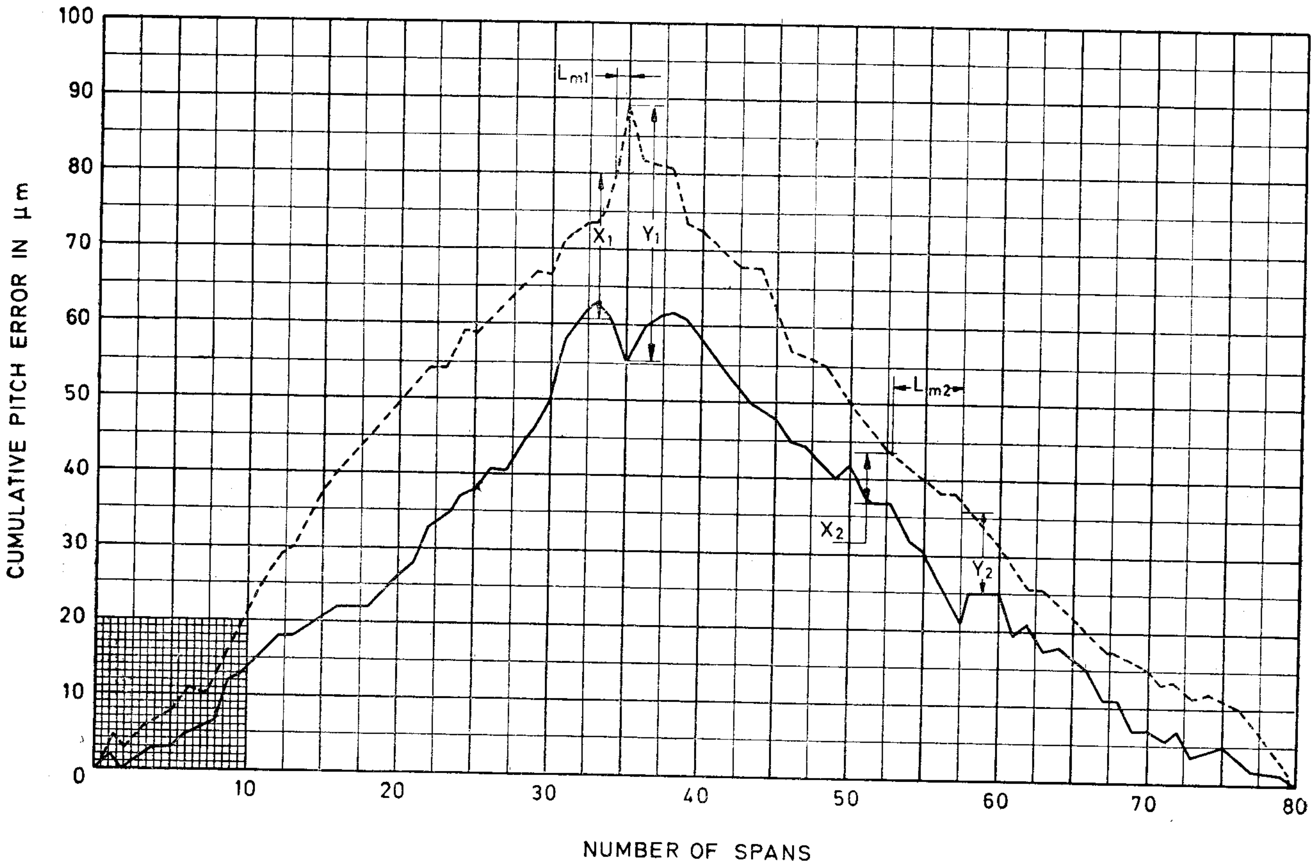

Fig. 9 Matching of Cumulative Pitch Errors

Example 2 :

Length of arc corresponding to five spans from span 53 to span 58

$$L_{m2} = 5 \times 8 \times 18{\cdot}849\,6$$
$$= 753{\cdot}98 \text{ mm}$$

Allowable cumulative pitch error from **6.2.3** for Class A2 is
$1{\cdot}25\sqrt{753{\cdot}98} + 3{\cdot}3 = 37{\cdot}62\ \mu m$

Allowable matching error from **6.2.4** is $0{\cdot}5 \times (37{\cdot}62) + 8 = 26{\cdot}81\ \mu m$

From Fig. 9; $X_2 = 6{\cdot}858\ \mu m$ corresponding to span 53
$Y_2 = 10{\cdot}922\ \mu m$ corresponding to span 58

Matching error $= Y_2 - X_2$
$= 10{\cdot}922 - 6{\cdot}858$
$= 4{\cdot}064\ \mu m$, which is less than the amount permitted

INDIAN STANDARDS

ON

GEARS

IS:

2458-1965	Glossary of terms for toothed gearing
2467-1963	Notation for toothed gearing
2535-1978	Basic rack and modules of cylindrical gears for general engineering and heavy engineering (*second revision*)
3681-1966	General plan for spur and helical gears
3734-1966	Dimensions for worm gearing
3756-1966	Method for gear correction
4058-1967	Accuracy requirements for coarse quality low speed gears
4059-1967	Accuracy requirements for medium quality medium speed gears
4071-1967	Master gears (module range 1 : 25 to 10)
4160-1967	Method for rating of machine cut spur and helical gears
4702-1968	Accuracy requirements for high precision gears
4725-1968	Accuracy requirements for precision gears
5037-1969	Basic rack and modules of straight bevel gears for general engineering and heavy engineering
5267-1969	Glossary of terms for worm gears
5375-1969	Data for procurement of cylindrical gear
6535-1972	Data for procurement of straight bevel gears
7403-1974	Code of practice for selection of standard worm and helical gear boxes
7443-1974	Methods for load rating of worm gears
7504-1974	Methods of inspection of spur and helical gear
8830-1978	Basic requirements for marine gears
8843-1978	Accuracy requirements for turbine gears